AN INVESTIGATION INTO LOW ENVIRONMENTAL IMPACT ORDNANCE DISPOSAL METHODS WITH BALLISTIC DISCS

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ABSTRACT

We report on the development of standoff Explosive Ordnance Disposal (EOD) operations with ballistic discs where safety and the minimisation of environmental impact of the explosive effects are of prime importance. Ballistic discs were selected since they can be designed to contain relatively small amounts of explosive (i.e. less than 100g) and low density case materials to minimise overpressure, fragmentation and site damage. Two EOD methods were investigated. One method was aimed at neutralising the munition fuze while leaving the body and filling intact. The other method was aimed at opening the munition case and producing a slow burn of the filling in a single operation.

Our methodology involved evaluating ballistic disc designs using numerical modelling and instrumented firings. Short listed candidates were field tested against 105mm HE shell and 81mm mortars (representing thick and thin cased munitions).

A ballistic disc design was produced that had 100% success in neutralising the fuze and ejecting it from the munition case providing the aim position was away from the booster. Flash radiography showed that the fuze train was disrupted in less then 50μs and the projectile was captured within the broken-up fuze assembly.

A reproducible technique for producing a slow burn of the explosive filling was not proven. A set of conditions has been produced where the case is cracked open with part or full consumption of the filling by slow burning.

Tests showed that the ballistic disc projectile was stopped within the thickness of a sandbag

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and ricochet did not occur for oblique angles of attack; thus there would not appear to be a down-range hazard. Other test demonstrated that sandbags placed over the ballistic disc did not impair its performance but removed any case fragmentation hazard and reduced the overpressure hazard to a low level.

1.0 INTRODUCTION

The disposal of ordnance by ballistic disc (also termed explosively formed projectiles, EFP) techniques offers the potential of producing events that have a low environmental impact. Interest in the approach arises from increasing difficulties in disposal operations which detonate the offending ordnance in-situ. To realise their potential low environmental impact techniques are required to provide minimum overpressure, ground shock and fragmentation that would otherwise have an adverse effect on neighbours, nearby installations and sensitive environmental areas. The problem may be approached using ballistic discs in two ways. One approach is to neutralise the fuze (or render safe procedure, RSP) followed by removal of the remaining parts of the munition for disposal at an appropriate remote location. The other approach is to penetrate and open the munition case with the aim of producing low order reactions of the filling. Reported work by Spenser of AFEODTC in the US (1) and Thomlinson of DRA Fort Halstead in the UK (2) produced promising results but high order reactions with detonation of the filling were sometimes observed.

In this paper we present a summary of the results of an investigation into the use of various ballistic disc designs to either neutralise fuzes or produce low order reactions of the explosive filling. Tested ordnance were 81mm mortar and 105mm shell.

2.0 BENEFITS OF BALLISTIC DISC TECHNIQUES

Proven ballistic disc techniques have the potential of offering significant benefits for Explosive Ordnance Disposal, EOD, operations. The components are cheap and disposable and the logistics of deployment are aided by field fabrication with plastic explosive filling. Ballistic discs can be designed with relatively small amounts of explosive filling (i.e. about 100g or less) and low density case materials to minimise overpressure and fragmentation effects. No supporting equipment is required other than a simple detonator firing device; hence there is no chance of lost equipment if the round produces a high order event. Importantly the ballistic disc device is stood off from the offending munition and the standoff distance is not critical since projectiles can be produced that are stable in flight. Alignment of the projectile with the designated hit position is not difficult. Thus there is no requirement to disturb the round and this has clear benefits when dealing with damaged or hazardous ordnance or if the round is suspected of being booby-trapped.

Projectile velocities produced by ballistic discs are typically in the range 1.2 to 3km/s which are sufficient to penetrate and not ricochet from the case for an angled attack. (see Section 4.3). By firing the device in a downwards direction from a sandbag type support a misaligned projectile will be captured by the ground. Furthermore our results show that ballistic discs can be designed such that the projectile is contained within the ordnance or fuze and thus there is no residual penetration or overshoot. Sandbagging of the ballistic disc device can be used to muffle its overpressure and fragmentation effects.

3.0 INVESTIGATION METHODOLOGY

3.1 General

In order to optimise the design of the ballistic disc disposal device a large range of designs were investigated; parameters varied included explosive head height, case material and disc material, shape, thickness profile and diameter. Our method involved a combination of hydrocode modelling and instrumented experiments followed by full scale field tests.

We considered that the type of projectile required for both fuze neutralisation and low order burn techniques would have a large diameter without producing excessive penetration of the target ordnance. The large diameter would maximise damage to the fuze or produce a large hole diameter in the case for the low order technique to encourage venting of any reaction products and thus reduce the tendency for the build-up of higher order events (explosions, deflagration to detonation transitions). In order to minimise the explosive content of the device the aim was to maximise the projectile diameter with respect to the device calibre. The limit on penetration depth was considered to be a balance between being able to perforate the range of available munition cases but avoid excessive penetration through the explosive filling which would be expected to facilitate explosive reaction.

Initially the Dyna 2D hydrocode was used to model the selected ballistic disc design to estimate the projectile velocity, diameter, shape and stability up to about 12 charge diameters standoff. Projectiles which exhibited large diameters (with respect to the disc diameter), velocities in the 1-2 km/s range and stable flight shapes after formation were selected for penetration studies. Dyna 2D was used to model the projectile penetration in steel of the selected designs. Steel was selected for the penetration studies because of its widespread use for munition cases. Devices which produced relatively large diameter holes without excessive penetration (i.e.less than 40mm) and whose hole profiles remained approximately constant with standoff were subjected to experimental verification. Laboratory examination of the short listed ballistic discs involved multiple flash radiography to check the projectile characteristics and penetration studies into steel at a range of standoffs.

The procedure for selecting candidate glass ballistic discs was based only on the experimental measurements since we lacked the material algorithms for glass for incorporation into the hydrocode.

Generally the agreement between the Dyna 2D hydrocode predictions and experiment were good as shown by the example in Figure 1.

Final assessment was made by field testing the short listed candidate designs against 105mm HOW HE M1 Shell and 81mm mortar both filled with Composition B and containing pressed Tetryl boosters. The 105mm shell was taken as representative of thick cased munitions and the 81 mm mortar taken as representative of thin cased munitions.

A total of 37 ballistic disc designs were evaluated. These included copper, steel and glass liners and aluminium and plexiglass cases. Explosive head heights ranged from ¼ to one charge diameter. Summary sheets were produced for each ballistic disc design evaluated depicting the projectiles penetration characteristics in steel; an example is shown in Figure 2. The explosive filling used for all tests was Plastic Explosive 4 which contains approximately 88% RDX and 12% inert additives. This was handfilled into the devices immediately prior to testing.

3.2 Field Tests

The aim positions for the fuze neutralisation tests varied from 10mm from the fuze/munition case junction towards the nose to directly in line with the booster charge, these locations are shown in Figure 3. The field set-up using a ballistic disc device for fuze neutralisation is shown in Figure 4. The ballistic disc was mostly positioned on a sandbag that was tamped to align the projectile with the designated hit position on the projectile. In some shots the device was located on a simple, specifically developed stand with an alignment rod. For most shots the munition was placed on a steel witness plate to assist with the diagnostics if a violent event occurred. Two or three sandbags were placed about 100mm from the nose of the fuze, normal to the munition axis to catch the ejected fuze components.

After each shot the nose area of the munition body was inspected for damage and the state of the internal contents (i.e. filling, remnants of the booster and fuze body). If a violent reaction had occurred the witness plate was inspected to determine whether an explosion/deflagration had occurred or a detonation. When the fuze was ejected the adjacent sandbags were emptied and the fuze components recovered for inspection.

Four fuze/munition combinations were tested. These were an 81mm mortar with M532 and PDM524A6 fuzes and a 105mm shell with PDM 557 and PDM 739 fuzes.

The field set-up for the investigation into producing a low order burn of the munition filling is shown in Figure 5. Several different aim positions on the munition body were used to assess the viability of the technique. They included positions normal to the base end (105mm shell only), near the base normal to the case axis, at several positions along the axis of the body including midway and close to the supplementary charge and normal to the top of the curvature of the case at the midpoint region along the munition axis. The majority of these tests were conducted with 105mm shell and 81mm mortar fitted with inert plugs which represent the fuze (PRF). The presence of the PRF aided the interpretation of the result since any violent reaction would result from the projectile/case/filling interaction and not the fuze functioning or booster reaction.

4.0 RESULTS AND DISCUSSION

4.1 Fuze Neutralisation

The study showed that the most successful ballistic disc design for fuze neutralisation contained a 60mm diameter copper disc 2mm thick within a plexiglas case.

The results are detailed in reference 3 and when compared to the aim point diagram in Figure 3 demonstrate that all tests with aim points well away from the booster position removed the fuze from the munition without any reaction of the main charge. For these tests the recovered munition was within about a meter of the original position and location with sandbags was successful. The only damage to the shell body was the evidence of the ballistic disc projectile entry position. Examination of the contents of the sandbags adjacent to the original position of the fuze showed that they captured the majority of the fuze components and fragments. A result from a fuzed 105mm shell is shown in Figure 6. This simple technique allowed rapid recovery of the ogive, plunger, fuze train, etc and thus would expedite EOD operations. Some shots were aimed at the booster position and produced some reaction of the main filling that fragmented the case to varying degrees. Reference to Figure 3 shows that the booster in the fuze used in the mortar is significantly closer to the fuze/case junction than that for the 105mm shell/fuze combination; this explains the variation in the production of deflagration events observed with these fuze/munition combinations.

The aim point at the fuze/case junction produced successful results for all fuze/munition combinations tested except the PDM739/105mm shell combination. The PDM 739 fuze/105mm shell tests produced events that split the case and consumed part of the main filling. This result is subject to further study since the projectile aim position was not in line with the fuze booster. Tests at aim points several millimetres towards the nose away from the PDM 739/105mm shell case junction produced fuze breakup without any main filling reaction or case breakup.

In most shots the projectile remnant was recovered adjacent to the original fuze position. Inspection of the munition case showed no exit hole indicating that the projectile was captured by the fuze assembly.

A comparative test was undertaken using a 38mm diameter conventional shaped charge containing a 42° apex angle copper cone filled with Composition B. This charge produces a high velocity jet with a tip velocity of 7.4 km/s and with a diameter about 1.5 mm. The aim point was the fuze/case junction of the 105 mm shell. A hole several millimetres in diameter was produced through the fuze/case junction. The major part of the damaged fuze was still attached to the shell. With the state of the explosive components in the fuze in an unknown condition the event was an unacceptable result and demonstrates the importance of using the larger diameter, slower type of projectile produced by a ballistic disc device.

A flash radiographic sequence of photographs showed the disruption process of the fuze by the ballistic disc projectile. The radiographs also showed that after impact and its initial penetration, the projectile was captured within the fuze; thus supporting the field observations. The estimated time between projectile contact with the target assembly and complete disintegration of the fuze debris from the munition case was about 300μs. However, we estimate that the time between projectile contact with the round and disruption of the fuze train was less than 50μs.

4.2 Low Order Reaction Technique

The range of events obtained in the tests aimed at obtaining low order reaction of the filling can be classified as follows:

- (a) failure to penetrate the munition case,
- (b) case penetration followed by limited slow burning of the filling,
- (C) case penetration followed by slow burning that consumes the contents of the filling (taking 15-25 minutes),
- (d) case penetration, splitting of the case with some or all consumption of the filling. Negligible fragment projection,
- (e) case penetration followed by explosion or deflagration of the filling, fragment projection up to a few hundred metres,
- (f) detonation of the round.

Our study was aimed at producing type (c) and type (d) events where there was negligible fragment throw and overpressure produced by the offending ordnance was minimal. Work on the low order technique concentrated on 105mm shell as this was considered a more difficult disposal problem with its thick case. The following comments are based on an examination of the detailed results which are given in reference 4.

Tests aimed at various positions normal to the longitudinal axis of the shell produced the full range of results with about 50% of the events being classified as acceptable (type (c) and (d)). An example of a type (d) event is shown in Figure 7. Tests aimed normal to the base end of the 105mm shell with 80mm diameter devices with copper liners produced a majority of slow burning events (type (c)) with no detonations (7 slow burns and 3 deflagrations). This aim position is relevant to impacted rounds where the base end may be the only portion of the round readily avialable to the EOD operator. Tests aimed close to the base normal to the longitudinal axis of the munition produced about 50% of burns but the higher order events included a detonation.

The most successful aim position for the 105mm shell tests was mid-way along the body 35mm up from the centre line. At this aim position the 60mm diameter device containing a 2mm thick copper liner produced 5 out of 5 successful events where the case split open and the explosive filling was completely or partially consumed. A similar device but containing a low carbon steel liner also produced a set of successful events i.e. 3 out of 3 tests

Tests against 81mm mortar were inclined to split the case around the circumference at the obscurating band position (slower projectiles) or produce violent events (faster projectiles). Some success was obtained for projectiles aimed towards the tail and above the centre line. These charges had reduced heights of explosive filling and split the case with some consumption of the filling.

4.3 Muffling of Ballistic Disc Explosive Effects

Methods were investigated to muffle the fragment and overpressure effects from the ballistic disc device. Several designs of thick walled steel tubes into which the ballistic disc was placed were ineffective. A sufficiently robust container was rejected as adding complexity, cost and logistical deployment problems to the technique. Various sandbag arrangements were trialled and an effective set-up was produced. This involved the placement of a simple cover over the ballistic disc followed by 3-4 layers of sandbags around all sides except the forward facing direction. The firing cable was lead through the sandbags. The cover over the ballistic disc prevented the sandbags making contact with it thus avoiding any disturbance to the alignment and aim position with respect to the munition.

The sandbag muffle was displaced on firing but it contained the ballistic disc case fragments and reduced the overpressure to 5kPa (0.7 psi) at 6m. A test with a sandbag target demonstrated that the projectile from the ballistic disc was stopped and eroded within a single sandbag. Another ancillary set of tests confirmed that the projectile did not ricochet for inclinations at least up to 70° to a steel target surface.

5.0 CONCLUSION

We have demonstrated that a cheap, simple ballistic disc device can produce a projectile that can neutralise a fuze by disruption and ejection from the munition case without reaction of the main filling. Our results also show that the projectile should not be aimed towards the booster position or there is a likelihood of a violent reaction of the main filling.

A reproducible technique for producing a slow burn of the explosive filling has not been proven. A set of conditions has been determined where the case is opened with part or full consumption of the filling by slow burning. Reactions from 105mm shell were more extensively investigated than those from 81mm mortar.

Ancillary tests showed that the ballistic disc projectile could be stopped within a single sandbag. A layer of 3-4 sandbags placed over the device (except the forward direction) muffled the case fragmentation and reduced the overpressure to 5kpa (0.7 psi) at 6m.

6.0 ACKNOWLEDGEMENTS

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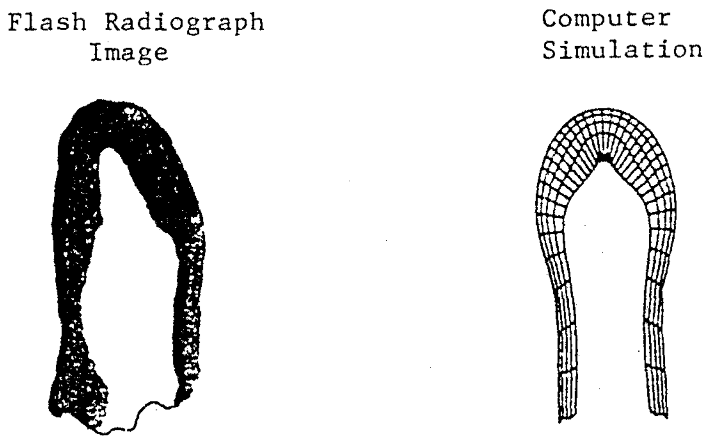
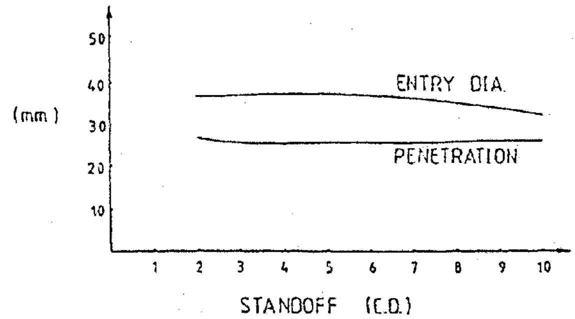


FIGURE 1. Comparison of computer code prediction and the image from flash radiography of a ballistic disc projectile.

R 60 COPPER CAP (ϕ 60 mm)

STANDOFF (C.D.)	2	4	6	10
ENTRY DIAMETER (mm)	37	37	37	32·5
PENETRATION (mm)	27	25	26	26

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT.
J.T.V. = 1·6 mm/µs



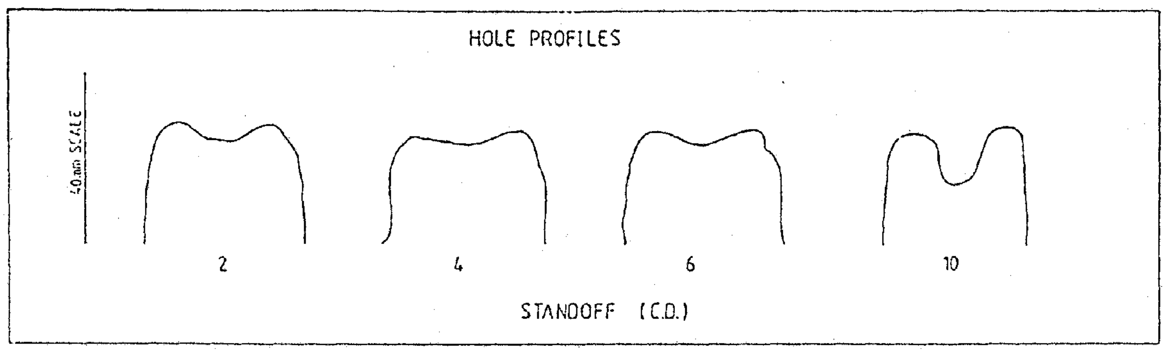


FIGURE 2. Example of a summary sheet showing the penetration of a ballistic disc into steel.

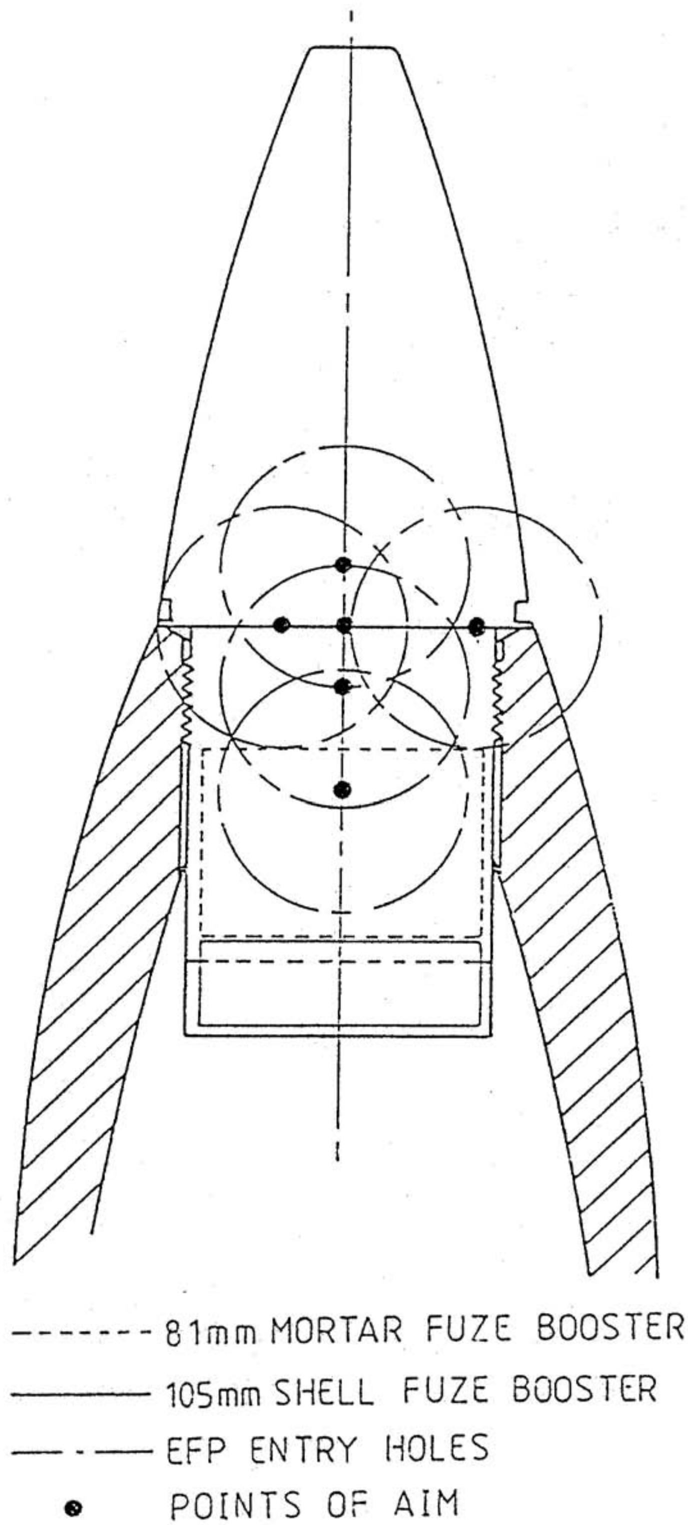


FIGURE 3. Aim positions for fuze neutralisation tests.

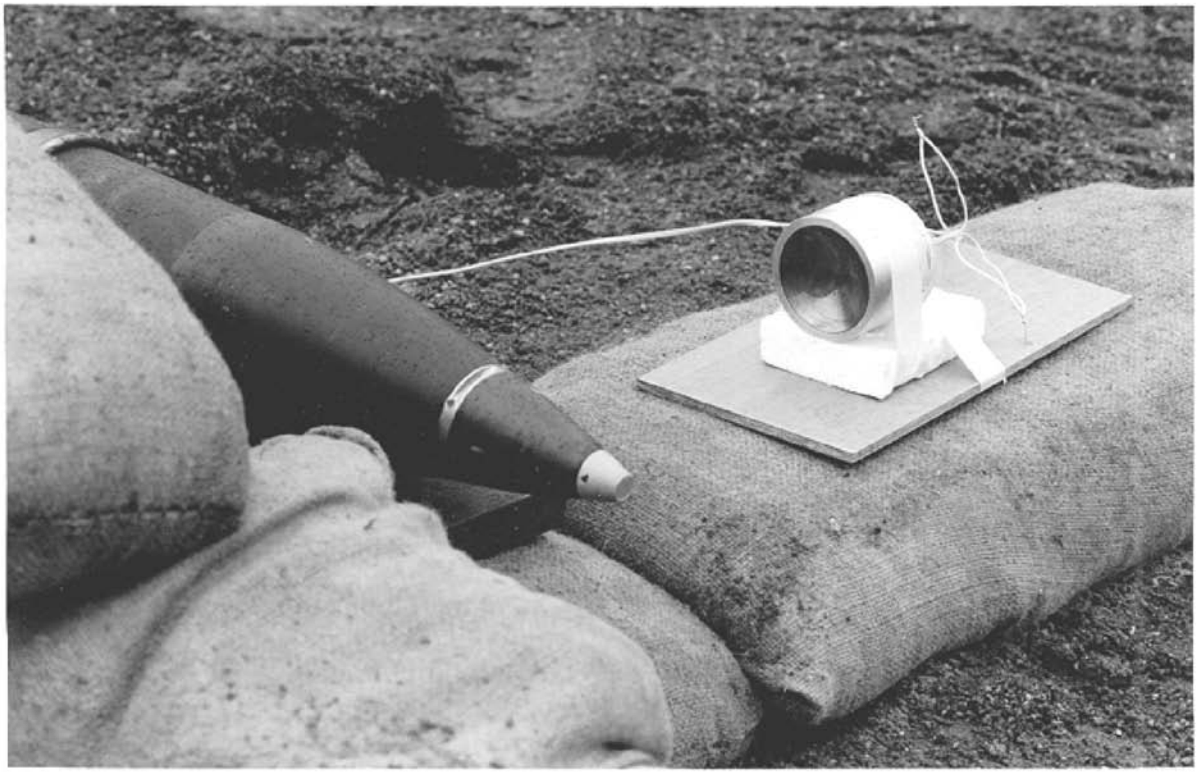


FIGURE 4. Field set-up for fuze neutralisation with a ballistic disc.

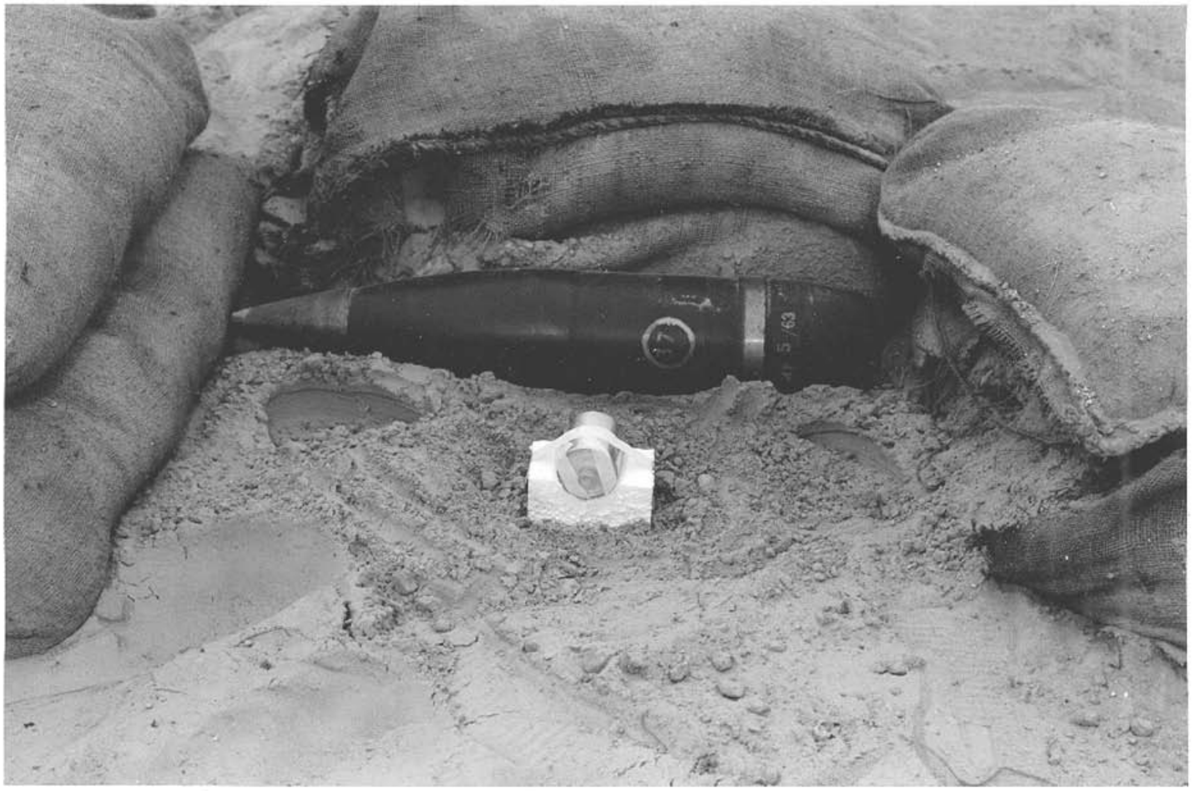


FIGURE 5. Field set-up investigating low order munition disposal with a ballistic disc.

FIGURE 6. Result from the ballistic disc neutralisation of a fuzed 105mm HE shell.

FIGURE 7. Result from ballistic disc strike on the central region of a Composition B filled 105 mm HE shell.